New Appraisal Method for Blocking Effects in Subimage Coding

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Abstract

Considering the human visual masking property, a modified relationship between the activity function and the visibility threshold is developed. This leads to a novel objective appraisal method for blocking effects in a lossy subimge coding by virtue of the human visual sensitivity. The appraisal criterion is examined using a series of reconstructed images that are DCT-coded at various bit rates. Experimental results show that the presented blocking effect measure well agrees with the subjective ranking.

I. Introduction

In the field of visual communications, the image compression is essential for many emerging applications. Among many the block-based video image coding techniques have been by far the most popular. Here, the images are typically divided into spatially partitioned subblocks, i.e., 8x8 or 16x16, over which a transform is performed and each subblock is compressed independently. This block-by-block coding enables one to efficiently process the image information adaptively and parallelly. For instance, majority of emerging image and video compression standards, including CCITT H.261 [1], JPEG [2] and MPEG [3] adopt the subblock discrete cosine trasform(DCT) coding methods. In the subblock-based coding, however, only the correlation between the pixels within the same subblock is considered and the correlations among different subblocks are completely neglected. If the required compression bit rate is relatively low, the visually disturbing blocking edge artifacts occur in the reconstructed image due to the quantization errors caused by independent processing of subblocks. This phenomenon is called the block effect and the human visual system is extremely sensitive to these boundaries in the image.

To quantitatively assess the reconstructed image quality, the measures such as the signal-to-noise ratio or mean squared errors, etc., are conventionally used. However, in a reconstructed image with block effects, this generic appraisal technique is not appropriate since sometimes the higher the signal-to-noise ratio is, the worse its subjective quality could be. In other words the SNR measure cannot be solely employed to reflect the human visual perception of errors. Since human observers are the end users of the image information, the subjective perception of human vision to the image can be another decisive appraisal for the subjective image quality. This collectively results in the subjective ranking [4]. This appraisal method, however, is not always convenient in practice and, frequently, the result attained could be unstable.

In the following we present an alternative objective appraisal method which can quantitatively assess the block effect in the reconstructed image. In Section 2 the activity function which is a measure of details in the locality of a picture is constructed and, on the basis of subjective comparison tests, a relationship is then obtained between the activity function and the visibility threshold. In Section 3 the simulations are performed using a series of reconstructed images resulted from the 8x8 subblock DCT coding at different bit rates in order to assess the block effects using our criterion. Finally, the appraisal standards for different degree block effects are given.

II. New Appraisal Measure for Blocking Effects

The perception sensitivity of the human vision to the image reconstruction artifacts is of nonlinearity with the image spatial details. The results reported by Fiorentini, Vassilev and Limb [2],[3],[4] demonstrate that with the

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increase of the image edge slant the visual perceptivity of the variation in the images also increases; and the sensitivity variation of the signals which lie relatively far from image edges decreases correspondingly. This indicates that the errors appeared in the flat region of the image are much more sensitive to the eyes than those in the detail areas of the images. Furthermore, according to the human visual mask effect, the human vision possesses varying degrees of tolerance to small errors on different backgrounds. The errors occuring at or adjacent to the areas with large signal changes are less visible than that occurred in the flat areas of the picture, even though they have the same intensity.

Conventionally, the visibility threshold has been widely used to quantify the human visual sensitivity. It is a measurement of the just-not-visible signal difference. The reciprocal of the visibility threshold is defined as the sensitivity. Various subjective tests show that errors below a certain visibility threshold are not perceptible at all. On the other hand, the measurement of the image details can be obtained by determining activity coefficients of an image as follows:

$$\begin{aligned} A_n = \max[\ & |f(i,j)-f(i-1,j-1)|,\ |f(i,j)-f(i-1,j)|, \\ & |f(i,j)-f(i-1,j+1)|,\ |f(i,j)-f(i,j-1)|, \\ & |f(i,j)-f(i,j+1)|,\ |f(i,j)-f(i+1,j-1)|, \\ & |f(i,j)-f(i+1,j)|,\ |f(i,j)-f(i+1,j+1)|\ ] \end{aligned} \quad (1)$$

where A_n is the activity coefficient and $f(i,j)$ is the pixel value.

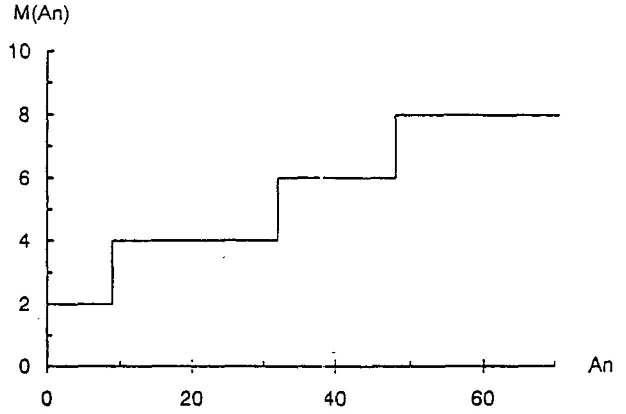


Fig. 1. The curve relating the activity function A_n vs. the visibility threshold $M(A_n)$.

Based on the results by Limb and Piersch [4] a new modified function relating the activity function and the visibility threshold effect is obtained through computer simulations and subjective comparison tests. As shown in Fig.1 the absolute difference between two adjacent pixels is below the corresponding visibility threshold, the human vision can not distinguish one signal from the other. Otherwise, the human eyes can perceive the difference. With this result obtained we have developed the block effect measurement algorithm.

In a subblock image compression coding, the block effect occurs because the subblocks are treated independently and the blocking effect mostly appears around on the connective boundary of the adjacent subblocks. For this reason this paper concerns mainly with those pixels of around the subblock boundary areas when we try to quantify the block effect. Specifically, for a point on the two adjacent subblock boundary, there exist two pixel points which belong to each one of the adjacent subblocks, respectively. If the difference taken as defined in Eq.(1) is within the allowed visual mask effect range, i.e., below the visibility threshold, the difference of these two signals would not be perceived by the human vision. In other words no block effect said to be occurred at that point. Otherwise, human eyes can perceive the difference of these two signals. This phenomenon is known as visible or, otherwise, invisible effect. It should be noted that not all the points with visible phenomenon can yield the block effects. If there exists an edge crossing two adjacent subblock boundary in the original image, the visible phenomenon which appears at the corresponding point on the edge is not regarded as the block effect. To determine the boundary pixel points involving the block effect let us examine the following cases:

case 1. If the point on the boundary of the adjacent subblocks in the reconstructed testing image is visible and the corresponding point on the boundary of the adjacent subblocks in the original reference image, i.e., the original image without block effect, is also visible, then this point is actually an edge pixel point in the original image, therefore it can not be regarded as a block effect point.

case 2. If the point on the boundary of the adjacent subblocks in the testing image is visible, and the corresponding point on the boundary of the adjacent subblocks in the original reference image is invisible, then this point must be a block effect point.

case 3. If the subblock boundary pixel point of the testing image is invisible, and the corresponding boundary pixel point in the réference image is visible, then this point can only be regarded as the blurred edge point in the original image, it is not a block effect point.

case 4. If the subblock boundary point of the testing image is invisible, and the corresponding boundary point in the reference image is also invisible, then this point naturally is not a block effect point.

According to the above image analysis, the Case 2 is the only possible situation in which the point on the boundary of the adjacent subblocks belongs to the block effect.

To demonstrate the extent of the block effect in the tested image the ratio between the total number of boundary points and the number of block effect points in the tested image is estimated as a quantitative measure of the corresponding visible block effect. Once those ratios are obtained a feasible determination algorithm to measure the block effect can then be designed. Consider the original reference image $F(i,j)$ and its reconstructed testing image $R(i,j)$, where $i = 1,2,3,\ldots,N$ and $j = 1,2,3,\ldots,N$ and let NBE be the total number of block effect points and NBTOL denote the total boundary points between the adjacent subblocks in the tested image. Assuming that the original image was sub-divided into 8x8 subblocks for coding, the possible block effect points are located at the positions of which Mod(i,8)=1, Mod(i,8)=0 or Mod(j,8)=1, Mod(j,8)=0 and $i,j \neq 1$ and $i,j \neq N$. Since the points on the boundary of the adjacent subblocks satisfy the conditions Mod(i,8)=1, Mod(i-1,8)=0 and Mod(j,8)=1 , Mod(j-1,8)=0, respectively, we need to consider only the two cases: Mod(i,8)=1 and Mod(j,8)=1. The more rigorous algorithm is as follows:

step 1. Initialize NBE and NBTOL.

step 2. Search the whole image along i and j axes. If the search reaches the end point of the image then go to Step 5.

step 3. If Mod(i,8) $\neq$ 1 or Mod(j,8) $\neq$ 1, or i,j=1 or i,j=N, then go back to Step 2.

step 4.

- **case 1.** If Mod(i,8)=1, the boundary point of the adjacent subblocks is located, then NBTOL =NBTOL+1. In this case the possible block effect point may appear on a line which is parallel to the axis j, and we choose $E_F = |F(i,j) - F(i-1,j)|$ and $E_R = |R(i,j) - R(i-1,j)|$.
- **case 2.** If Mod(j,8)=1, it is a boundary point of the adjacent subblocks, then NBTOL= NBTOL+1. In this case the possible block effect point may appear on a line which is parallel to the axis i, and we choose $E_F = |F(i,j) - F(i,j-1)|$ ans $E_R = |R(i,j) - R(i,j-1)|$.
- **case 3.** In an image with block effects, since the activity of a pixel may be destroyed by the block effect, the activity coefficient A_n of this pixel point should be calculated through Eq.(1) using the reference image. IF $E_F \leq M(A_n)$ and $E_R > M(A_n)$ then this point is a block effect point, and NBE=NBE+1. Return to the Step 2.

step 5. Calculate the ratio between the the total number of boundary points NBTOL and the number of block effect points NBE using SBC=NBE/NBTOL and then stop.

III. Experimental Results

Three CCITT standard pictures, i.e., Lena, Girl and Cronkite, are used in the simulation. Firstly, these pictures are subdivided into 8x8 subblocks and coded using the two-dimensional DCT. Referencing the MPEG [3] the DCT coefficient quantization algorithm the quantization step-size for the DCT coefficient of the subblock is set to 8. The AC coefficients ac(i,j) are first scaled by individual weighting factors W(i,j) [3] and $ac\sim(i,j) = 16 \cdot ac(i,j)/W(i,j)$. The step-size for quantizing the scaled DCT coefficients $ac\sim(i,j)$ are derived from the quantization parameter Mquant. The quantized level QAC(I,J) is given by

$$QAC(i,j) = ac\sim(i,j)/2 \cdot Mquant \tag{2}$$

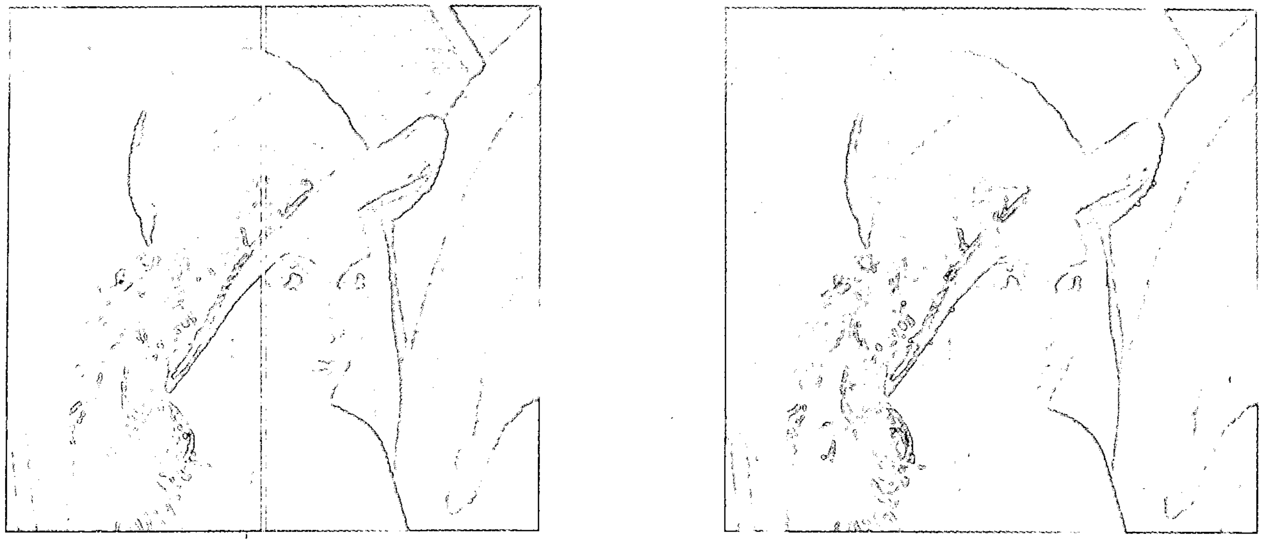
In the decoding process a series of reconstructed images are produced by applying the inverse two-dimensional DCT. The step-size can be changed by adjusting Mquant in Eq.(2) and, hence affects the reconstruction quality. The obvious block effects appear in the reconstructed images when Mquant reaches a critical value. As expected the higher the value Mquant is, the more serious the block effect is resulted. Using the reconstructed images along with the originals the further simlation is performed by applying our block effect appraisal algorithm. As mentioned forehand there exists varying degrees of block effects that are included in the reconstruction as shown in Fig.2. The subjective appraisals are made by a group of five professionals and five unprofessional people. The primary result is shown in Table 1.

Table 1. Our new quantitative measure of block effects.

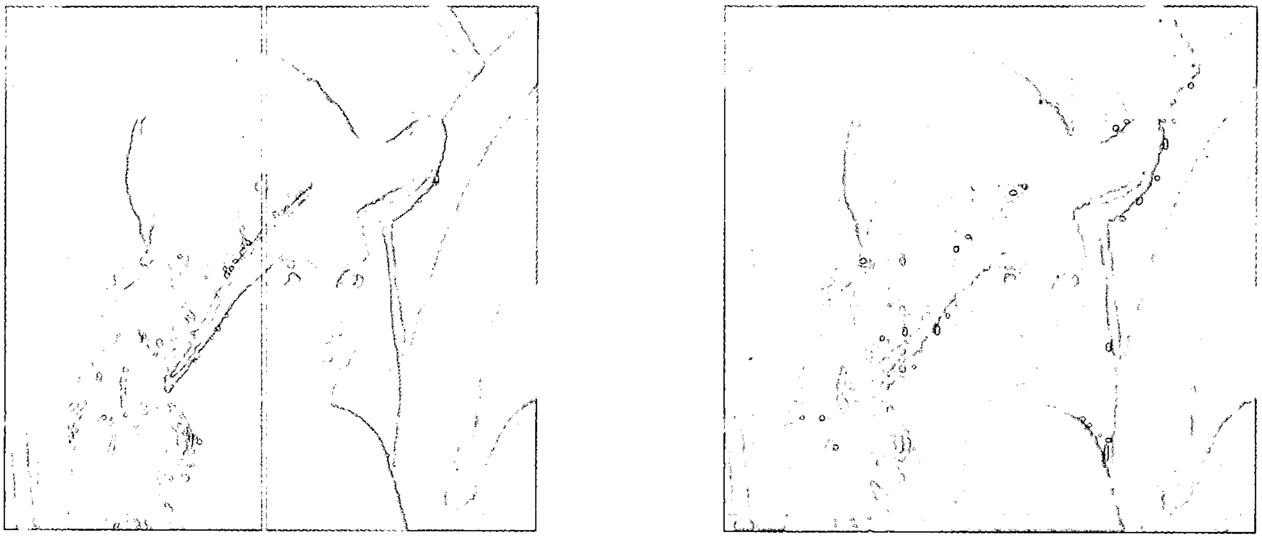
SBC	SBC=0	SBC < 4%	4% < SBC 15%	SBC > 1
Subjective Appraisal	Excellent 5 marks	Satisfied 4 marks	Acceptable 3 marks	Unacceptable 2 marks

IV. Conclusions

A novel algorithm that gives a quantitative measure of the block effect in the block-based lossy image compression coding has been presented in this paper. The modified relationship curve between the visibility threshold and the activity function is obtained based on the Limb and Pirsh



(a) 1.0bpp - 34.878 dB S..Rank=5 (b) 0.5bpp - 28.068 dB S.Rank = 4



(a) 0.4bpp - 26.534 dB S..Rank=3 (b) 0.3bpp - 23.988 dB S.Rank = 2

Fig. 2. Reconstructed Images of Lenna.

experiments [4], as well as our simulations and subjective comparison tests. The ratio between the number of block effect points over the total number of boundary points in the reconstructed image is used as an objective appraisal criterion for the block effect. The measure results by using this objective image quality appraisal agree well with the subjective ranking. To human vision, the details of the image is the most important factor to affect the visibility threshold. But the other factors, such as the background luminance, edge length, and edge amplitude etc., can also affect the visibility threshold. To get a more robust appraisal measure quantifying the reconstructed picture quality the more of such factors are under consideration and investigaed to improve the visibility judgement regulations.

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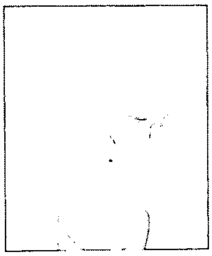

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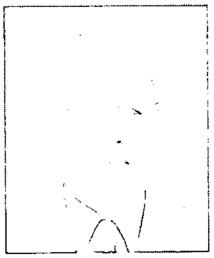

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